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Benefits of Leapfrogging to Super-efficiency and Low Global Warming Potential Refrigerants in Air Conditioning

Results from draft report

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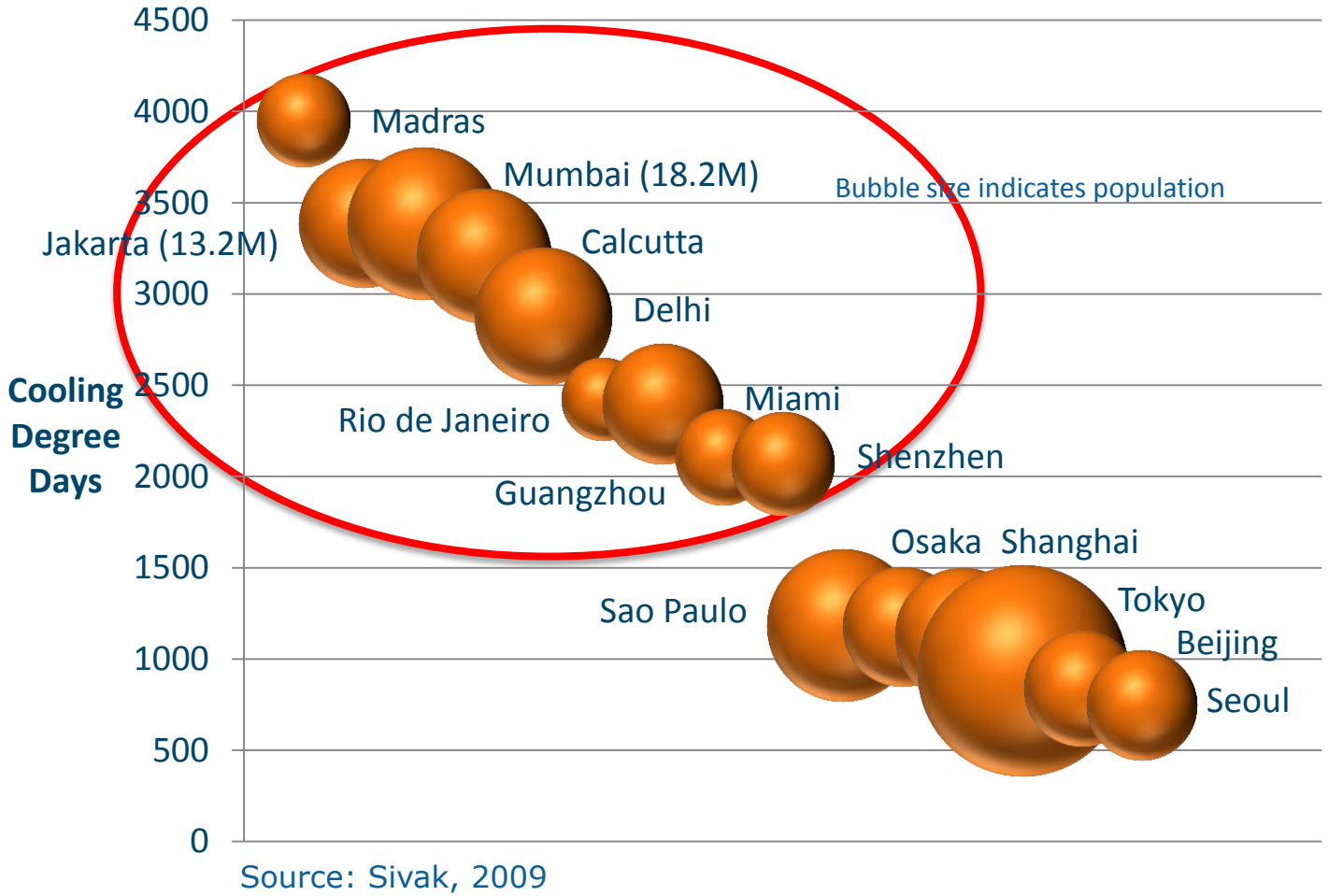
Outline

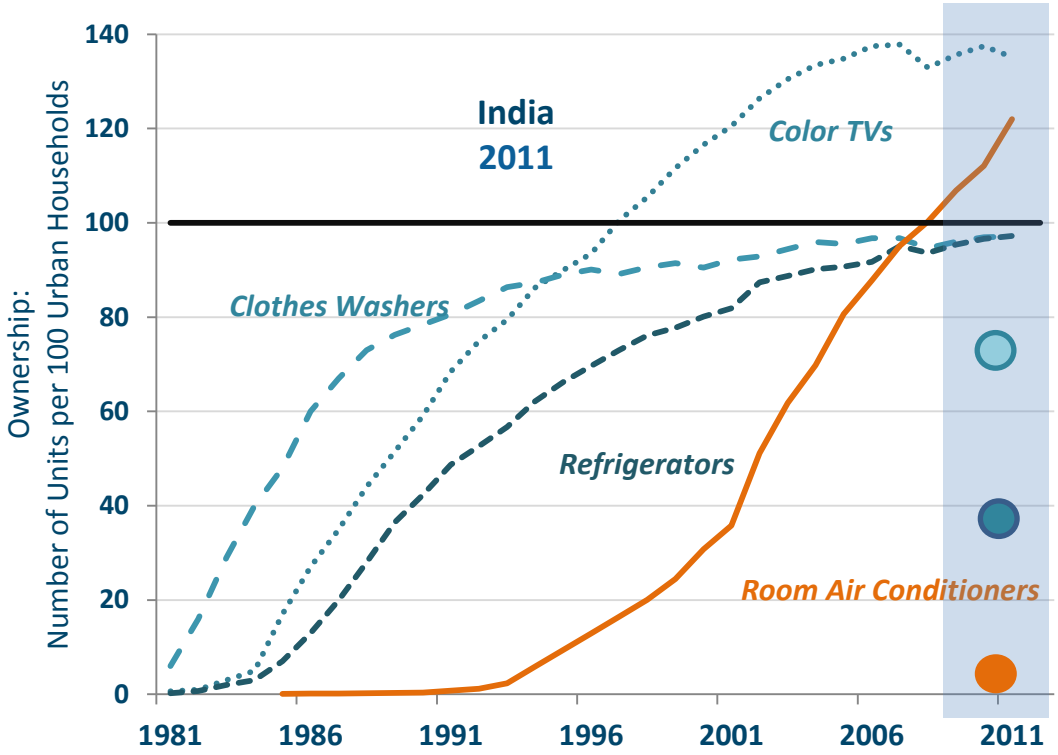
- Motivation and Recent Trends
- Methodology and Assumptions
- Draft Results
- Summary, next steps, discussion

High Cooling Energy Consumption in Largest Metros



Many of the world's most populous metropolitan areas have hot climates

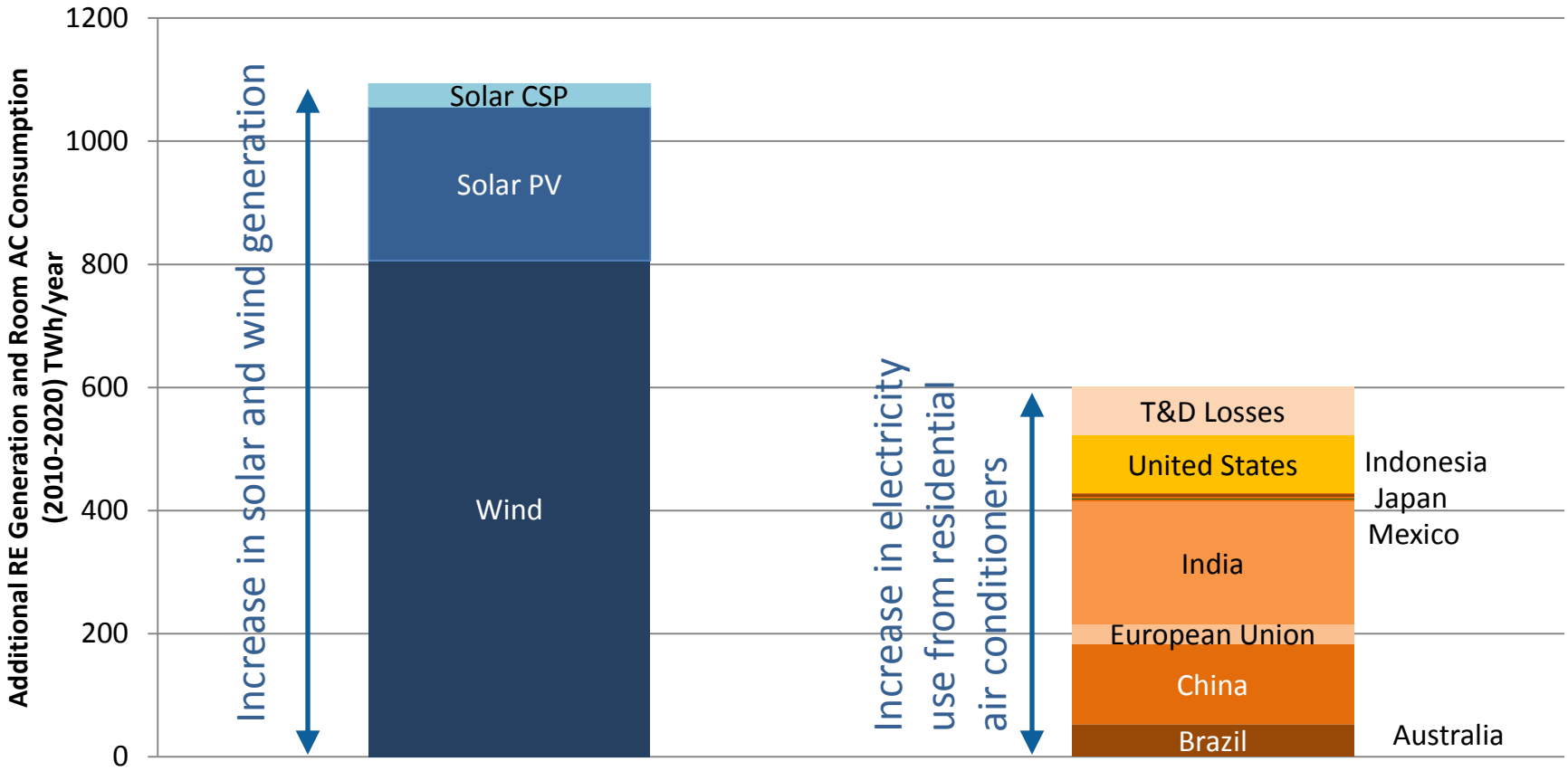
Example of High Growth—China



Source: NSSO, 2012, Fridley et al., 2012

- The AC ownership rate in urban China went from almost 0% in 1990s to over 100% in ~15 years.
- AC sales in major emerging economies are growing at rates similar to China circa 1994–1995, e.g., India room AC sales growing at ~10-15%/year, Brazil at ~20%/year (Shah et al., 2013).

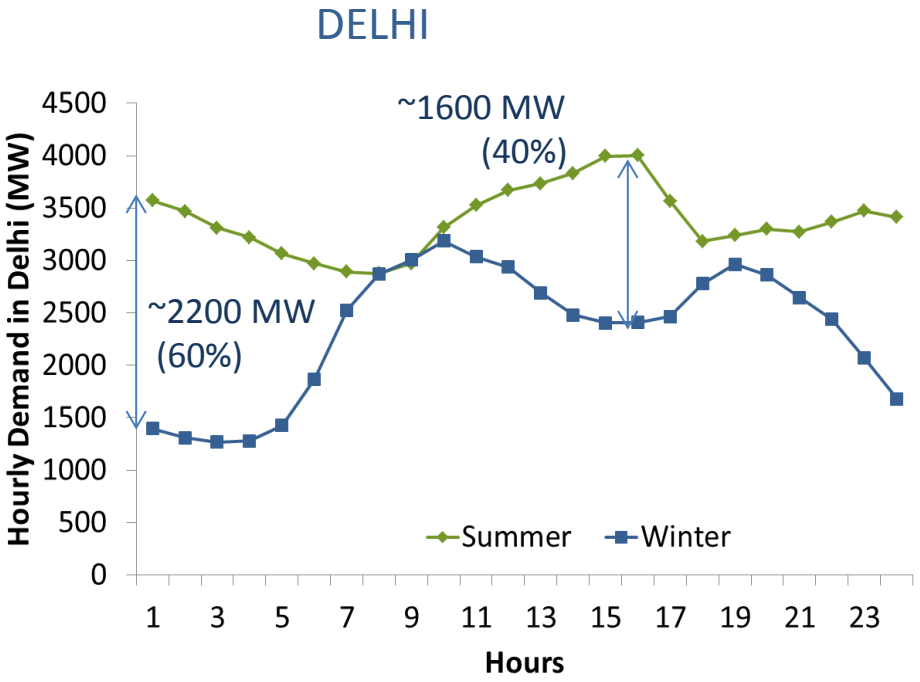
Growth in Renewable Generation and Cooling Energy, 2010–2020



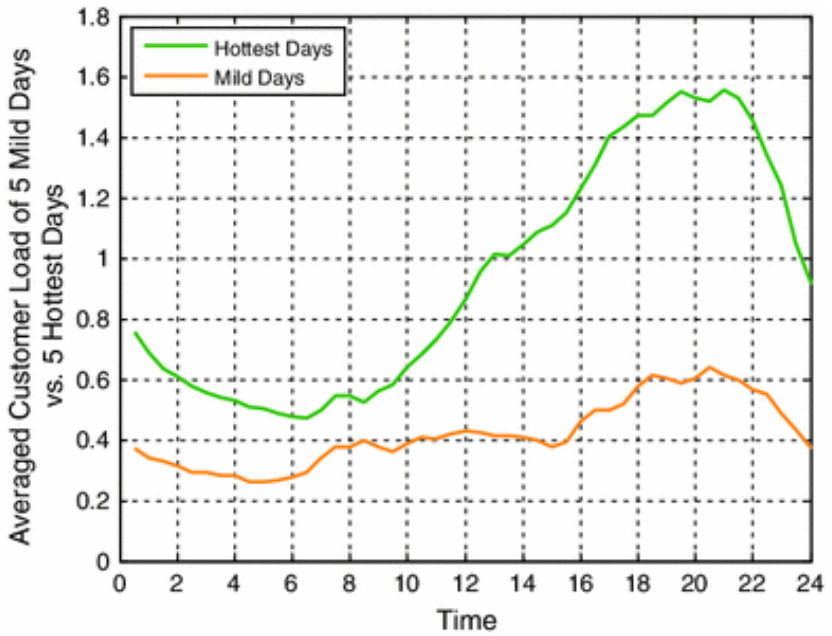
Renewable energy generation: IEA World Energy Outlook 2012 (Current Policies scenario). Residential air conditioning consumption: Shah et al. (2013); LBNL's Room AC analysis for the SEAD initiative; and V. Letschert et al. (2012), LBNL's BUENAS model.

Incremental electricity consumption from residential ACs alone is >50% of solar and wind generation projected to be added between 2010 and 2020.

Cooling has a Significant Peak Load Impact



Source: DSLDC, 2012



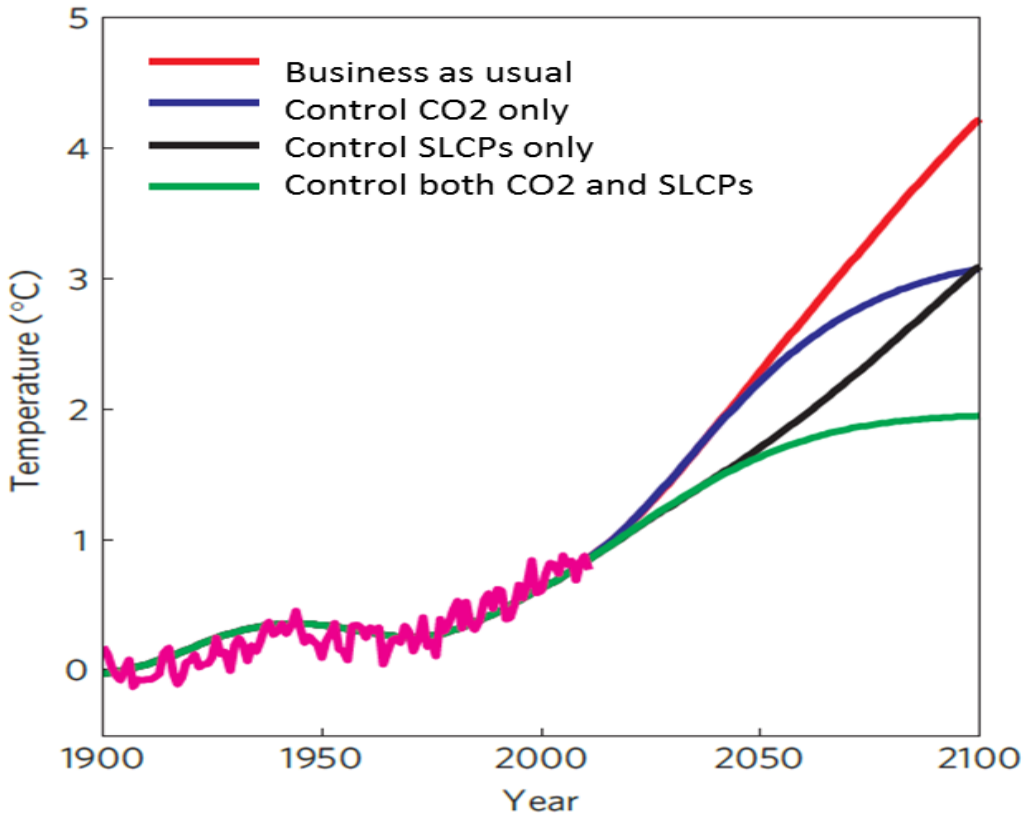
Ausgrid, Australia

Source: Smith et al., 2013

Cooling comprises 40%–60% of summer peak load in large metropolitan cities with hot climates, such as Delhi, India …

…and can triple load on the hottest days in some areas, e.g., New South Wales, Australia.

Control of CO_2 *and* HFC emissions needed



Source: Hu et al, 2013, Nature Climate Change

Is there a win-win opportunity to reduce *both CO_2 and HFC emissions* in air conditioning?

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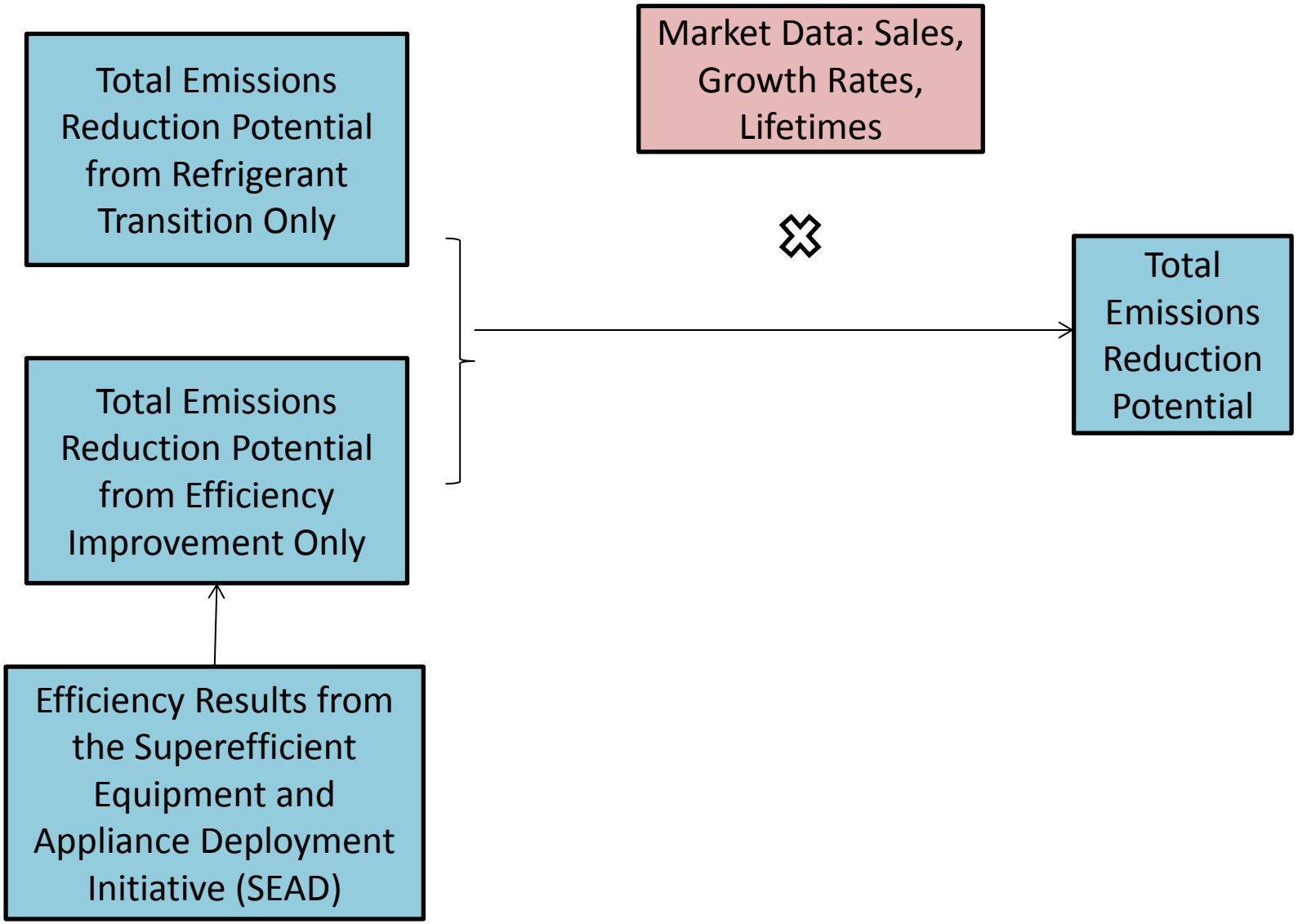
Structure of Model



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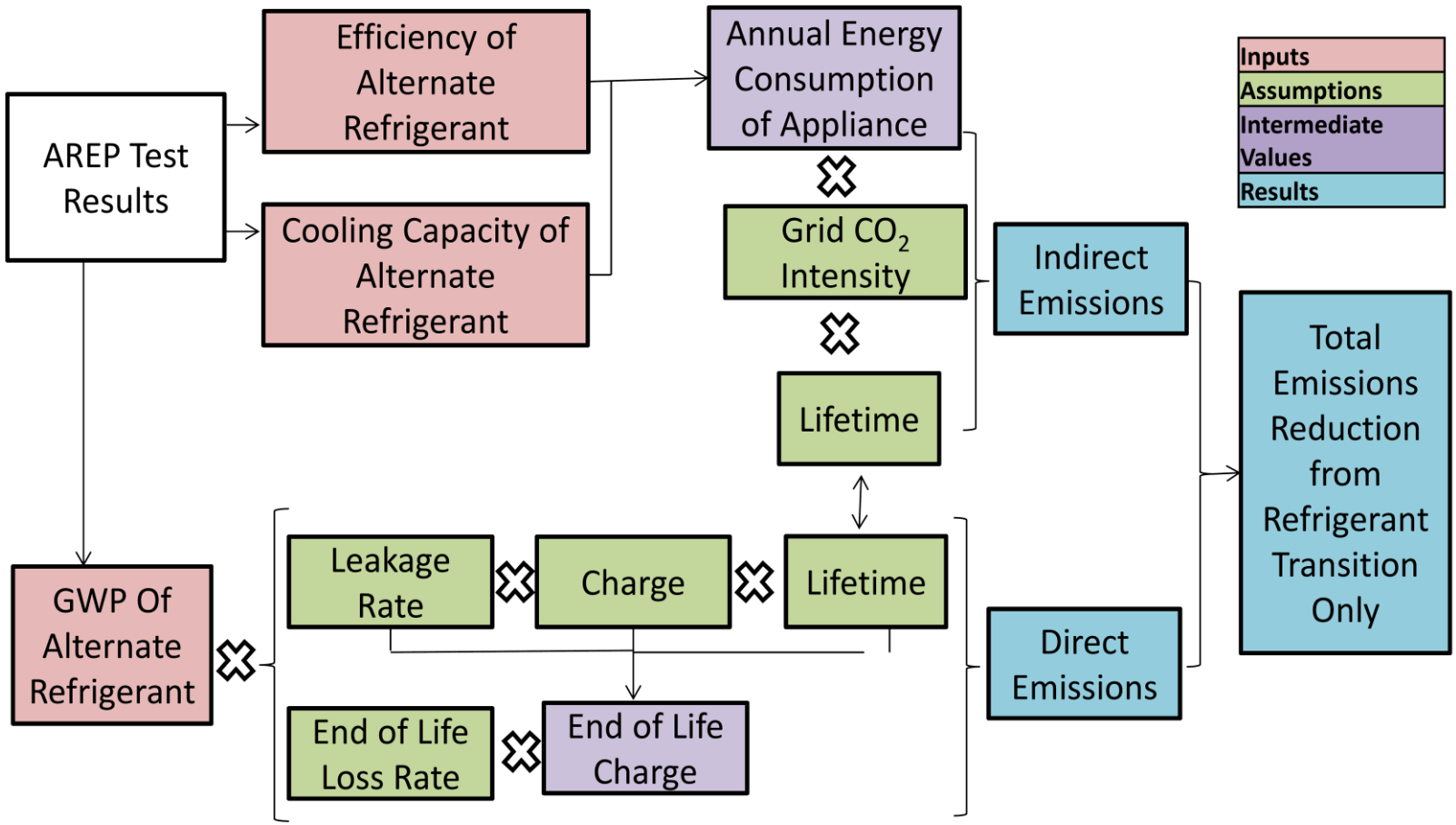


GWP: Global Warming Potential

AREP: Air-conditioning, Heating and Refrigeration Institute (AHRI) Low Global Warming Potential (GWP) Alternate Refrigerant Evaluation Program (AREP)

Base Case Assumptions

Cooling Capacity (tons)	1.5
Appliance Lifetime	10
Power Consumption (kW)	1.81
Energy Efficiency Ratio (W/W)	2.9
Refrigerant Charge (kg)	1.7
Refrigerant Leakage Rate(%/year)	10.0%
End of Life Refrigerant Loss Rate (kg)	100%
Recharge at % loss	35%
Charge/ton of AC capacity (kg/ton)	1.10
Number of recharges	2
Total Lifetime Charge Emitted (kg)	2.81
Total % Charge Emitted	170%

- **R410A 1.5 ton mini-split AC with 2.9 W/W Energy Efficiency Ratio(EER).**
- **1.5 tons is most popular cooling capacity in many global markets e.g. 60-65% of market in India.**
- **2.9 EER representative of "average" efficiency found on global market, close to many minimum standards (e.g. 2.7 EER in India and 3.1 in China)**

AHRI Low-GWP Alternate Refrigerant Evaluation Program (AREP) Phase 1(2012-2014) & Phase 2 (ongoing)

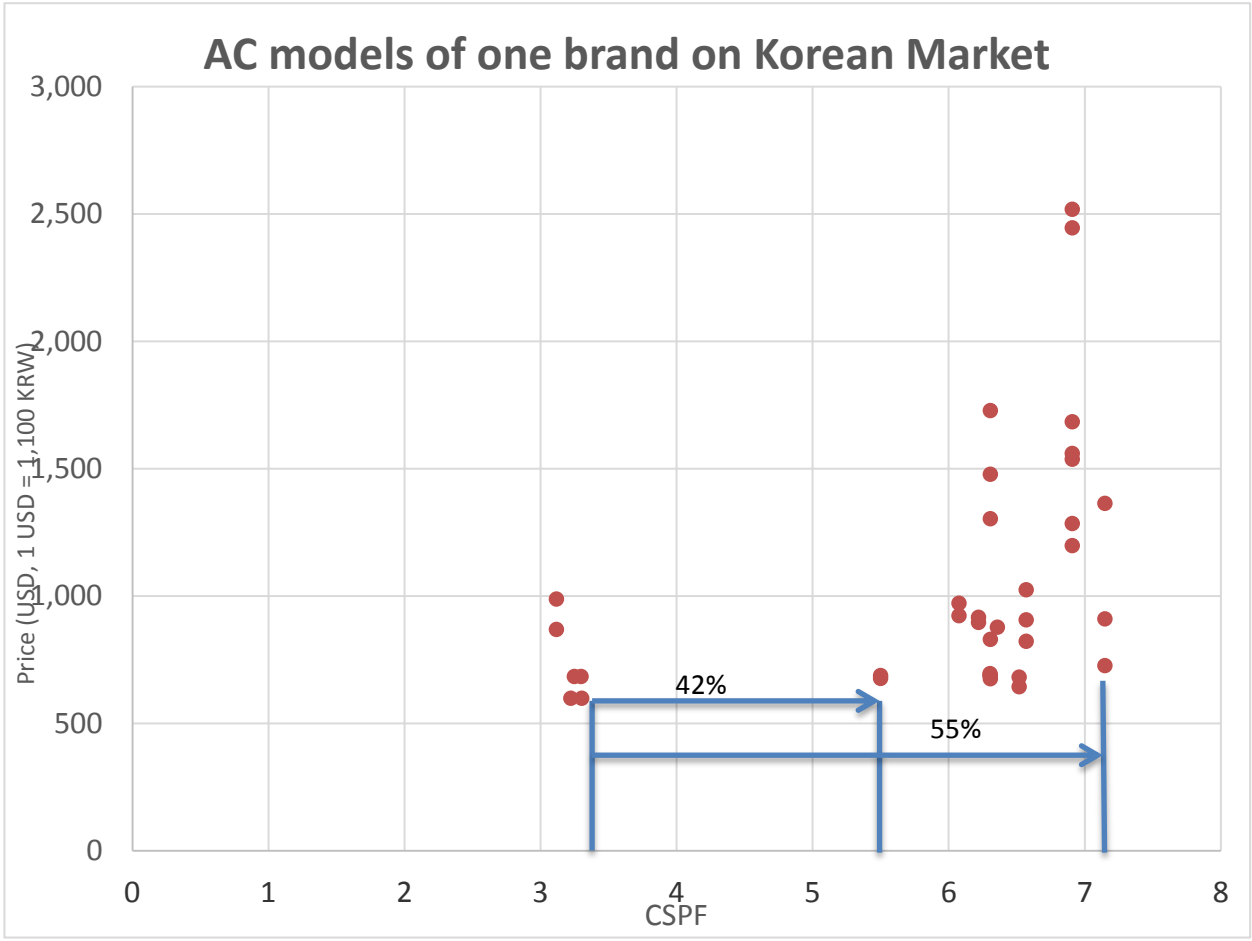
Baseline	Refrigerant	Composition	(Mass%)	Classification	GWP_{100}
R410A GWP=1924 (IPCC AR5)	ARM-70a	R-32/R-134a/R-1234yf	(50/10/40)	A2L*	469
	D2Y60	R-32/R-1234yf	(40/60)	A2L*	271
	DR-5	R-32/R-1234yf	(72.5/27.5)	A2L*	491
	HPR1D	R-32/R-744/R-1234ze(E)	(60/6/34)	A2L*	407
	L41a	R-32/R-1234yf/R-1234ze(E)	(73/15/12)	A2L*	494
	L41b	R-32/R-1234ze(E)	(73/27)	A2L*	494
	R32	R32	100	A2L	677
	R32/R134a	R-32/R-134a	(95/5)	A2L*	708
	R32/R152a	R-32/R-152a	(95/5)	A2L*	650

*estimated safety group rating, a safety group has not yet been assigned by ASHRAE in accordance with requirements of ASHRAE Standard 34-2013

Source: AHRI, 2014

- Voluntary co-operative research and testing program to identify suitable alternatives to high-GWP refrigerants.
- Standard reporting format for candidate refrigerants strongly desired by industry.

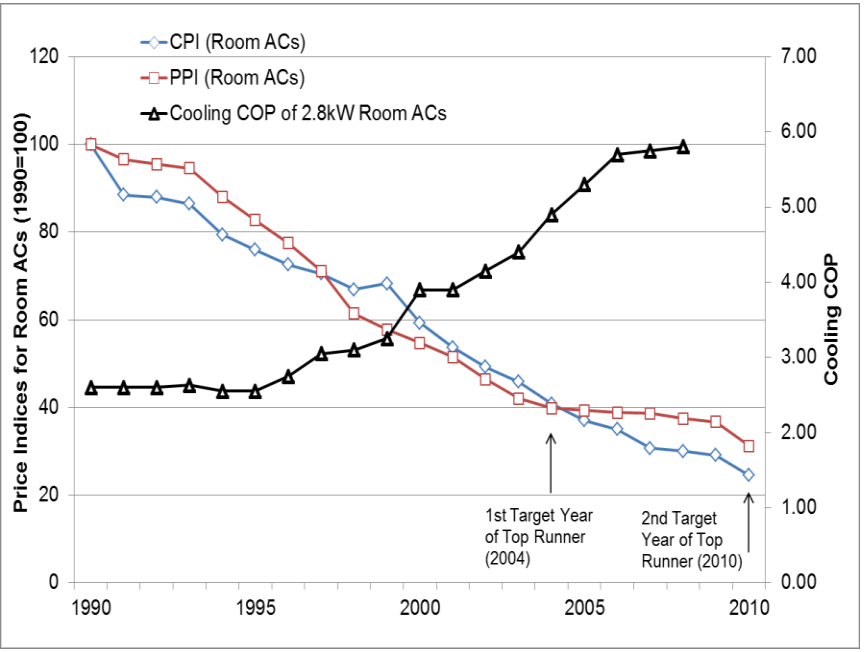
Significant efficiency improvement potential



Source: KEMCO, 2015

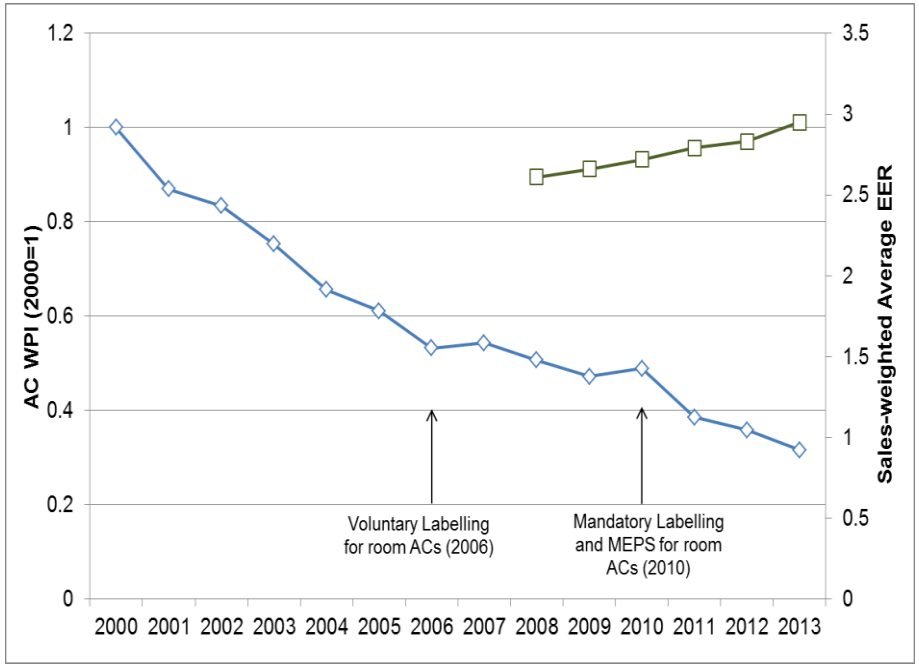
Efficiency improvement of ~40% is commercially possible today!

Falling Prices



Source: Kimura 2010 and Shibata, 2012

Japan



Source: OEA, 2013

India

AC prices continue to fall globally, even when efficiency improvement policies are implemented.

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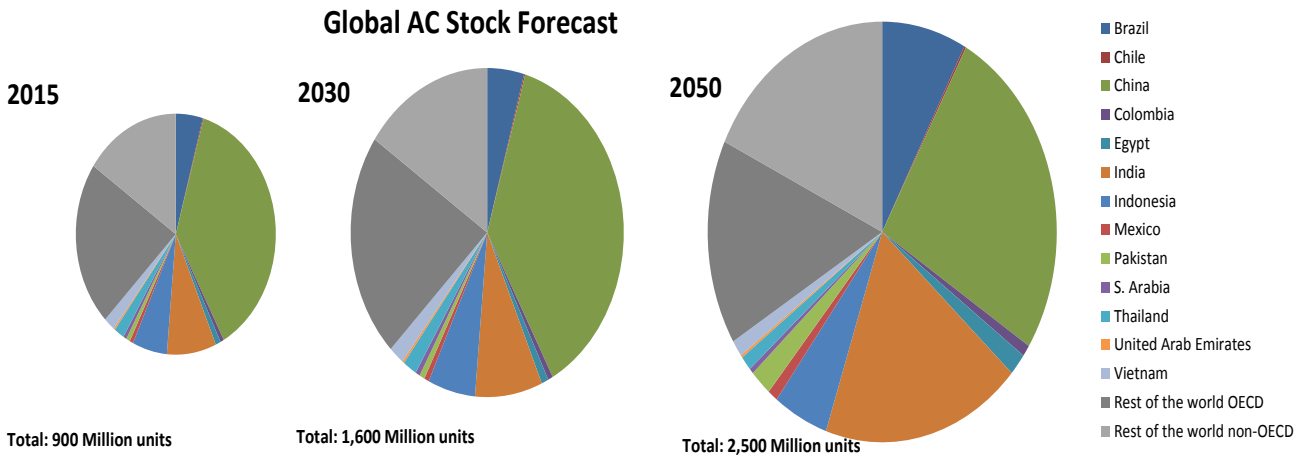
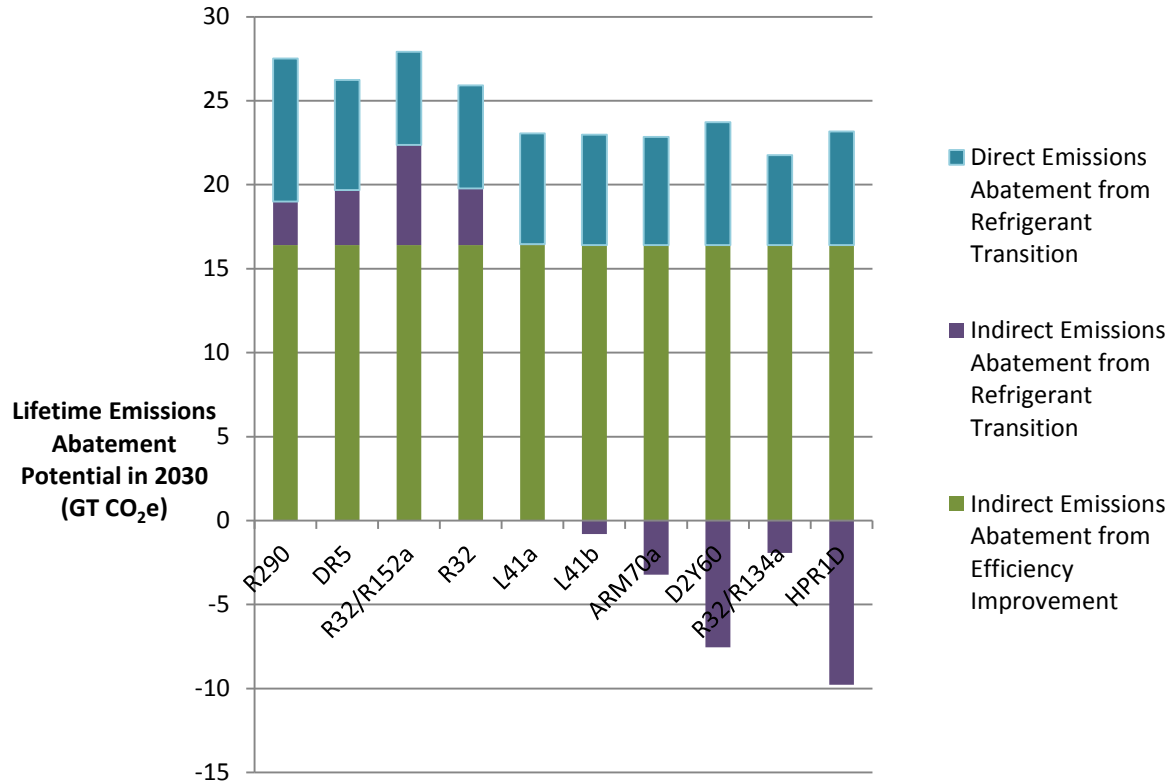
Draft Results – Current and Future Estimated Stock

	Sales-based 2015 Stock (Millions)		
	Residential	Commercial	Total
Brazil	17.5	11.6	29.1
Chile	0.4	0.7	1.1
China*	326.7	146.8	473.5
Colombia	0.8	0.6	1.4
Egypt	3.1	2.1	5.2
India	14	4.7	18.7
Indonesia	10.5	7	17.6
Mexico	4.1	0.9	5.1
Pakistan	1.7	0.6	2.2
S. Arabia	4.7	1.2	5.9
Thailand	8.4	5.1	13.5
United Arab Emirates	2.1	0.6	2.7
Vietnam	5.1	2.1	7.2
Total	399.3	183.9	583.2



Global Room AC stock is estimated to grow significantly from now till 2050 with much of the growth in major emerging economies such as India, Brazil and Indonesia

Draft Results – Global Lifetime Emissions Reduction in 2030



	Efficiency	Ref Transition
Brazil	23%	77%
Chile	46%	54%
China	62%	38%
Colombia	55%	45%
Egypt	62%	38%
India	74%	26%
Indonesia	69%	31%
Mexico	61%	39%
S. Arabia	64%	36%
Thailand	76%	24%
United Arab Emirates	59%	41%
Vietnam	74%	26%
Pakistan	66%	34%
Average	61%	39%

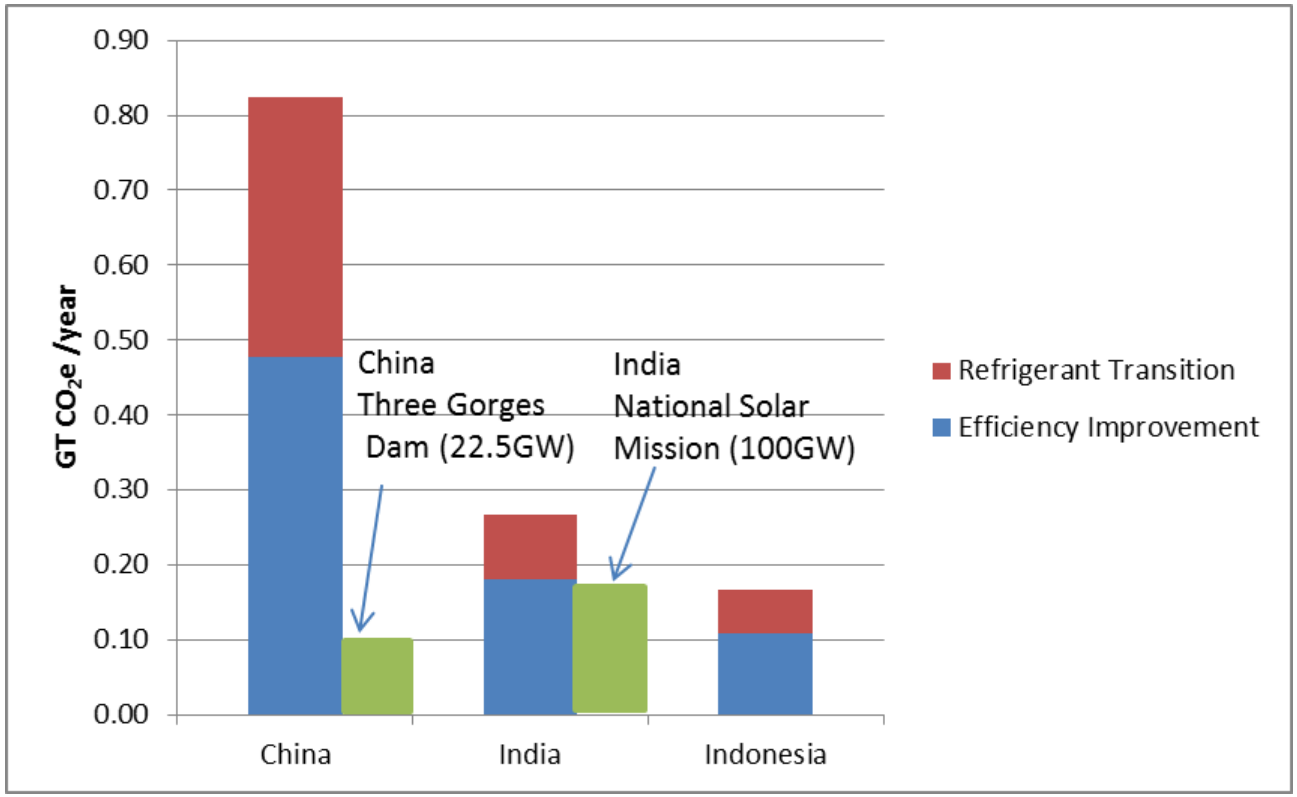
- **Efficiency improvement of ACs along with refrigerant transition roughly *doubles the emissions benefit* of either policy undertaken in isolation.**
- **Countries with higher hours of use or a more carbon-intensive grid benefit more from efficiency.**

Draft Results – Reduction in 2030 and 2050 Peak Load (GW)

	2030				2050			
	Efficiency improvement	Refrigerant transition	Efficiency Improvement & Refrigerant transition	Number of Avoided 500 MW Peak Power Plants	Efficiency improvement	Refrigerant transition	Efficiency Improvement & Refrigerant transition	Number of Avoided 500 MW Peak Power Plants
Brazil	14-32	2.3-5.4	**15.4-36**	**31-72**	41.3-96.4	6.9-16.1	**46-108**	**92-216**
Chile	0.44 -1.0	0.1-0.2	**0.5-1.1**	**1-2**	0.9- 2.2	0.2-0.4	**1.0-2.0**	**2-4**
China	118 -277	20-46	**132-310**	**264-620**	138.5-323.2	23.1-54	**155-361**	**310-720**
Colombia	1.9-4.3	0.3-0.7	**2.1-4.8**	**4-10**	4.7-10.9	0.8-1.8	**5.0-12.0**	**10-24**
Egypt	2.6-6.2	0.4-1.0	**3.0-7.0**	**6-14**	9.0-21.0	1.5-3.5	**10.0-23.0**	**20-46**
India	25.2-58.9	4.20 -9.8	**28-66**	**56-130**	98-229	16.4-38.2	**110-256**	**220-510**
Indonesia	17.8-41.5	3.0-7.0	**20-46**	**40-92**	27-63	4.5-10.5	**30-71**	**60-140**
Mexico	1.8-4.2	0.3-0.7	**2.0-4.7**	**4-10**	5-11.6	0.8-1.9	**5.5-13**	**11-26**
Pakistan	1.2-2.9	0.21-0.48	**1.0-3.0**	**2-6**	8.0-19	1-3.0	**9.0-21**	**18-42**
Saudi Arabia	1.7-4.0	0.3-0.7	**2-4.4**	**4-9**	2.2-5.1	0.4-0.9	**2.4-6**	**5-12**
Thailand	5.2-12.2	0.9-2.0	**6-13.7**	**12-28**	6-13.8	1-2.3	**6.6-15**	**14-30**
UAE	0.71-1.7	0.1-0.3	**0.8-1.9**	**2-4**	1-2.3	0.2-0.4	**1.1-3**	**2-6**
Vietnam	5.8-13.4	1-2.2	**6.4-15**	**13-30**	6.7-15.7	1.1-2.6	**7.5-18**	**15-36**
Global	302-705	50-117	**338-788**	**676-1576**	487-1137	81-190	**544-1270**	**1090-2540**

- **Efficiency improvement of ACs along with refrigerant transition has a significant peak load reduction potential.**
- **Countries with higher hours of use, and larger AC markets show more peak load reduction.**

Draft Results - Annual GHG Impact of AC policies in 2030



Transformation of the AC industry to produce super –efficient ACs and low GWP refrigerants in 2030 could provide GHG savings of 0.85 GT/year annually in China equivalent to over **8 Three Gorges dams** and over 0.32 GT/year annually in India, roughly **twice India's solar mission.**

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Summary and Next Steps

- Trends show significant estimated growth in the AC market particularly in major emerging economies.
- Large scale impact of air conditioning on electricity generation and peak load, particularly in hot climates and populous countries.
- Efficiency improvement of ACs along with refrigerant transition roughly doubles the emissions impact rather than either policy implemented in isolation.
- Countries with higher hours of use benefit more from efficiency.
- Efficiency improvement of ACs along with refrigerant transition shows significant peak load reduction.
- Next steps: - Incorporate results from ongoing high ambient temperature testing.
  - Respond to feedback and comments.

Questions, Suggestions?

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